INTERACTIVE EXPLORATION OF LOCAL STRAIN ON ULTRASOUND IMAGES - A STEP CLOSER TOWARDS CLINICAL IMPLEMENTATION

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Introduction

In competitive sports, tendinopathies are among the most common injuries, mostly caused by tendon overuse.
Nowadays, the diagnosis of these tendon related diseases is commonly performed using 2D ultrasound through visual evaluation. This adds no further information leading to therapeutic differentiation or optimisation and makes it difficult to detect the disease in earlier stages.
However, physicians believe that this extra diagnostic information can be obtained via a biomechanical approach where strain is evaluated. Typically, strain is estimated in a global manner by tracking both the insertion and origin of the tendon while this is being stretched. In our approach we estimate strain locally adding valuable diagnostic information regarding the tendon biomechanics.

Methods

In order to estimate strain, 2D+t dynamic ultrasound images with high spatial and high temporal (100 fps) resolution were acquired using the ultrasound system Vevo2100 (FUJIFILM VisualSonics, Inc, Toronto,CA) with a MS250 linear transducer at a central frequency of 20MHz. .
Three ex-vivo sheep tendons were stretched between 0 and 5% of strain using a material-testing machine (Zwick Roell) and used to evaluate the performance of this application.
Each specimen was stretched twice, in an identical fashion, simultaneous with the acquisition of 2D+t ultrasound images. Afterwards, a pre-processing step, based on deformable image registration using Elastix [1,2] was applied between consecutive pairs of 2D images. The applied method used a B-spline transformation model in a multi-resolution scheme. The similarity measure for the registration was sum-of-squares difference and a quasi-newton optimizer was used. The output of this registration yielded a displacement field for all voxels of the image. These local displacement maps were composed from the first to the last time point resulting in the cumulative displacement map.
An interactive application was developed that receives as input the 2D+t images and the cumulative displacement map resulting from the pre-processing. Local analysis of tissue displacement and strain can be performed in this application iteratively by selecting a region of interest (Figure 1).

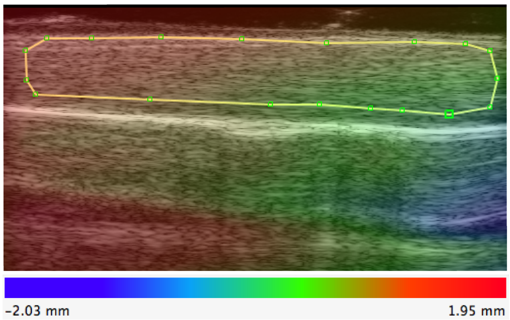

Figure 1 - Selection of region of interest within 2D ultrasound image of sheep tendon at 5% strain superimposed with a color map that represents the tissue displacement at this strain.

Results

The accurate evaluation of local strain estimations is very challenging as it is almost impossible to generate a ground-truth on real acquisitions. Therefore, we use a global average of the local strain within a subdivision of the region of interest as a surrogate and validate this with extensometers on the ex-vivo acquisition. We can see a very strong correlation (98%) between the global estimation of the strain and the strain measured by the extensometers. The absolute strain values are 6.83%, 2.5% and 1.8% in the three tendons, respectively, and are reproducible up to 0.15% in the repeated tests. These absolute values are different from the imposed strain and from the extensometer values. This can be justified by local variations of strain within the tendon or by the fact that the imaged region does not correspond to the maximum strain region or to the extensometer range of analysis.

Conclusions

This work shows promising results that bring the application of ultrasound based strain measurements in clinical scenarios closer to reality. However, further validation should confirm our preliminary conclusions and its benefit should be assessed in-vivo in pathological cases. In the long run, this work can support physicians to evaluate local abnormal deformations of tendons, guide rehabilitation and prevent major injuries in an easy, fast and straightforward manner.

References

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